

## **CERTIFICATE OF TRANSLATION**

**Re: Taiwanese Patent Application No. 91120859, Filed on September 12, 2002.**

**I, Yu-Ying Liang of TOP TEAM INTERNATIONAL PATENT & TRADEMARK OFFICE located at 3<sup>rd</sup> Fl., No.279, Sec.4, Hsin-Yi Rd., Taipei, Taiwan, R.O.C., hereby declare that I am the translator of the document attached and certify that the following is a true and accurate translation of the priority document to the best of my knowledge and belief.**

**Signature of Translator**

Yu - Ying Liang  
**Yu-Ying Liang**

**Dated this 3<sup>rd</sup> day of November, 2005**



**TITLE**

**METHOD OF FORMING A TRANSFLECTIVE LIQUID CRYSTAL DISPLAY DEVICE**  
**WITH WIDE-VIEWING ANGLE**

5 **ABSTRACT OF THE DISCLOSURE**

A method of forming a transflective liquid crystal display device with a wide-viewing angle. An insulating layer having an uneven surface is formed on a first substrate. At least a n opening is formed in the insulating layer. A reflective electrode is formed on a sidewall and a bottom of the opening and partial insulating layer. The reflective electrode has an opaque portion and a transparent portion, and the transparent portion is located in the opening. At least one symmetric protruding element is formed on the insulating layer around the reflective electrode. A conformal first alignment film is formed on the reflective electrode and the symmetric protruding element. A common electrode is formed on an inner surface of the second substrate. A second alignment film is formed on an inner surface of a the common electrode. Negative type liquid crystal molecules added with chiral agent fill in a space between the first and second alignment film to form a liquid crystal layer.

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## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

The present invention relates to a method of forming a transflective liquid crystal display device, and more particularly, to a method for increasing viewing angle of a transflective liquid crystal display device.

### **Description of the Related Art**

Liquid crystal display devices are classified into two types. One is a reflective type liquid crystal display device, and another is the transflective type liquid crystal display device using an external light source, such as sunlight or an indoor lamp. The reflective type LCD has the advantage of not requiring a backlight component, but it cannot operate without an external light source. The transflective type liquid crystal display can use external light and back light as light sources. Further, in comparison with the reflective type LCD device, the transflective LCD device has the advantage of operating as a transmission type LCD device using backlight when no external light is available. Therefore, transflective type liquid crystal displays are widely used in cell phones and PDA.

In general, the conventional transflective LCD devices use TN (Twisted Nematic) type liquid crystal molecules or MTN (Mixed mode TN) type liquid crystal molecules. The biggest drawback of the TN/MTN mode LCD device is, however, its narrow viewing angle. Thus, the conventional transflective LCD device has a gray scale inversion problem under transmission mode, thereby degrading display quality.

### SUMMARY OF THE INVENTION

An object of the present invention is to provide a method for increasing viewing angle of a transflective liquid crystal display device.

5        Another object of the present invention is to provide a method of forming a transflective liquid crystal display device with continuous domain liquid crystal alignment.

10        In order to achieve these objects, the present invention provides a method of forming a transflective liquid crystal display device with a wide-viewing angle. A first substrate and a second substrate opposite the first substrate are provided. An insulating layer having an uneven surface is formed on the first substrate. At least one opening is formed in the insulating layer. A conformal reflective electrode is formed  
15        on a sidewall and a bottom of the opening and part of the insulating layer, wherein the reflective electrode has at least one opaque portion and at least one transparent portion, and the transparent portion of the reflective electrode is located in the opening. At least one protruding element is formed on the  
20        insulating layer located around the reflective electrode. A conformal first alignment film is formed on the reflective electrode and the protruding element. A common electrode is formed on an inner surface of the second substrate. A second alignment film is formed on the common electrode. Negative type  
25        liquid crystal molecules added with a chiral agent are filled in a space between the first substrate and the second substrate to form a liquid crystal layer. When voltage is applied to the reflective electrode and the common electrode, an asymmetric electric field is generated around the reflective electrode.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reading the subsequent detailed description in conjunction with the examples and references made to the accompanying drawings, wherein:

Fig. 1A is a sectional view according to a first embodiment of the present invention while no voltage is present;

Fig. 1B is a sectional view according to a first embodiment of the present invention while an voltage is present;

Fig. 2A is a sectional view according to a second embodiment of the present invention while no voltage is present;

Fig. 2B is a sectional view according to a second embodiment of the present invention while an voltage is present; and

Fig. 3 is a top view showing the alignment of the liquid crystal molecules in one of the pixels of the transflective LCD device according to Figs. 1B and 2B while an voltage is applied thereto.

### DESCRIPTION OF THE REFERRANCES NUMBER

100~substrate;

110~transparent insulating layer;

120~opening;

130~reflective electrode;

132~opaque portion;

134~transparent portion;

140~first alignment film;

150~liquid crystal layer;

160~second alignment film;

170~common electrode;

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180~second substrate;

210~symmetric protruding element;

310~gate line;

320~data line;

5 330~pixel;

340~reflective area;

350~transmissive area.

## DETAILED DESCRIPTION OF THE INVENTION

### First Embodiment

Fig. 1A is a sectional view according to the first embodiment of the present invention while no external electric field is present. Fig. 1B is a sectional view according to a first embodiment of the present invention while an electric field is present. Fig. 3 is a top view showing the alignment of the liquid crystal molecules in one of the pixels of the transflective LCD device according to Fig. 1B while an electric field is applied thereto. In order to simplify the illustration, only one pixel cell is shown in Figs. 1A, 1B and 3.

In Figs. 1A and 1B, a first substrate 100 is provided. The first substrate 100 can be a glass panel having a thin film transistor array. The first substrate 100 is a light transmitting substrate so that light from a backlight (not shown) can penetrate the first substrate 100. Then, a transparent insulating layer 110 having an uneven surface is formed on the first substrate 100. Next, at least one opening 120 is formed in the insulating layer 110.

In Figs. 1A and 1B, a conformal reflective electrode 130 is formed on a sidewall and a bottom of the opening 120 and part of the insulating layer 110, wherein the reflective electrode 130 has at least one opaque portion 132 and at least one transparent portion 134. The transparent portion 134 of the reflective electrode 130 is located in the opening 120. The opaque portion 132 of the reflective electrode 130 can be an aluminum layer, and the transparent portion 134 of the reflective electrode 130 can be an ITO (indium tin oxide) layer. In Figs. 1A and 1B, a conformal first alignment film 140 is formed

on the reflective electrode 130. It should be noted that it is not necessary to perform a rubbing treatment on the first alignment film 140.

In Figs. 1A and 1B, a common electrode 170, such as an ITO layer, is formed on an inner surface of the second substrate 180. The second substrate 180 can be a glass panel having a color filter. Then, a second alignment film 160 is formed on the common electrode 170. It should be noted that it is not necessary to perform a rubbing treatment on the second alignment film 160.

In Figs. 1A and 1B, negative type liquid crystal molecules 152 added with a chiral agent fills in a space between the first substrate 100 and the second substrate 180 to form a liquid crystal layer 150, and a transflective LCD is thus obtained.

In Fig. 1A, when no pixel voltage (V) is present (or applied), the negative type liquid crystal molecules 152 are vertically aligned between the substrates 100 and 180 constituting the liquid crystal layer 150, thereby being a Normally Black state and enhancing the contrast in the reflective mode. In addition, the chiral agent makes the negative type liquid crystal molecules 152 have a twisting light property during an electric field is present, as shown as Fig. 1B. Moreover, the chiral agent causes the negative type liquid crystal molecules 152 to be stably disposed on the uneven surface of the reflective electrode 130.

In Fig. 1B, when a voltage (V) is applied between the reflective electrode 130 and the common electrode 170, since the periphery of the reflective electrode 130 has a section (or drop), an asymmetric electric field 190 occurs at a fringe portion of the reflective electrode 130. The asymmetric electric field 190 allows the negative type liquid crystal



molecules 152 added with the chiral agent to tilt and have different molecular alignment. Also, the negative type liquid crystal molecules 152 added with the chiral agent located around the opening 120 tilt toward the middle portion of the opening 120 due to a physical force (gravity effect). Hence, within the same pixel of the transflective LCD according to the invention, the molecules 152 have different molecular alignment (that is, many domains) so that the viewing angle of the transflective LCD is increased.

As shown in Fig. 3, a top view of liquid crystal alignment of FIG. 1B, in a single pixel structure 330 defined by a gate line 310 and a data line 320, the liquid crystal molecules 152 inside each pixel changes to display an image by employing an active device (such as a thin film transistor, not shown). In Fig. 3, the liquid crystal molecules 152 added with chiral agent according to the invention has a twisting light property and a continuous domain having different molecular alignment, thereby increasing the viewing angle of the transflective LCD. 340 corresponds to the non-transparent reflective area 132, and 350 corresponds to the transparent transmissible area 134.

### **Second Embodiment**

Fig. 2A is a sectional view according to a second embodiment of the present invention while no external electric field is present. Fig. 2B is a sectional view according to a second embodiment of the present invention while an electric field is present. Fig. 3 is a top view showing the alignment of the liquid crystal molecules in one of the pixels of the transflective LCD device according to Fig. 2B in one pixel while an electric field is applied thereto.

In Figs. 2A and 2B, a first substrate 100 is provided. The first substrate 100 can be a thin film transistor array included glass panel. The first substrate 100 is a light transmitting substrate so that light from a backlight (not shown) can penetrate the first substrate 100. Then, a transparent insulating layer 110 having an uneven surface is formed on the first substrate 100. Next, at least one opening 120 is formed in the insulating layer 110.

In Figs. 2A and 2B, a conformal reflective electrode 130 is formed on a sidewall and a bottom of the opening 120 and part of the insulating layer 110, wherein the reflective electrode 130 has at least one opaque portion 132 and at least one transparent portion 134. The transparent portion 134 of the reflective electrode 130 is located in the opening 120. The opaque portion 132 of the reflective electrode 130 can be an aluminum layer, and the transparent portion 134 of the reflective electrode 130 can be an ITO (indium tin oxide).

In Figs. 2A and 2B, at least one symmetric protruding element 210 is formed on the insulating layer 110 located around the periphery of the reflective electrode 130. The symmetric protruding element 210 preferably has a triangular cross-section. When voltage is applied to the liquid crystal display, due to the symmetric protruding element 210, liquid crystal modules around thereof can be arranged along a tile orientation, as shown in FIG. 2B.

A conformal first alignment film 140 is formed on the reflective electrode 130 and the symmetric protruding element 210. It should be noted that it is not necessary to perform a rubbing treatment on the first alignment film 140.

In Figs. 2A and 2B, a common electrode 170, such as an ITO layer, is formed on an inner surface of the second substrate 180. The second substrate 180 can be a glass panel having a color filter. The second substrate 180 is a light transmitting substrate. Then, a second alignment film 160 is formed on the common electrode 170. It should be noted that it is not necessary to perform a rubbing treatment on the second alignment film 160.

In Figs. 2A and 2B, negative type liquid crystal molecules 152 added with a chiral agent fills in a space between the first substrate 100 and the second substrate 180 to form a liquid crystal layer 150, and a transflective LCD is thus obtained.

In Fig. 2A, when no pixel voltage (V) is present (or applied), the negative type liquid crystal molecules 152 are vertically aligned between the substrates 100 and 180 constituting the liquid crystal layer 150, thereby a Normal Black state occurs enhancing the contrast in the reflective mode. In addition, the chiral agent causes the negative type liquid crystal molecules 152 to have a twisting light property when an electric field is present, as shown as Fig. 2B. Moreover, the chiral agent causes the negative type liquid crystal molecules 152 to be stably disposed on the uneven surface of the reflective electrode 130.

Since the periphery of the reflective electrode 130 has a section (or drop) and a protrusion 210, an asymmetric electric field 190 occurs at a fringe portion of the reflective electrode 130. The asymmetric electric field 190 allows the negative type liquid crystal molecules 152 added with the chiral agent to tilt and have different molecular alignment. Moreover, the liquid crystal molecules 152 near the protrusion 210 are tilted in a specific direction due to the local effect of the protrusion 210.

Also, the negative type liquid crystal molecules 152 added with the chiral agent located around the opening 120 tilt along a direction due to a physical force of gravity. Hence, within the same pixel of the transflective LCD according to the invention, the molecules 152 have different molecular alignment (that is, many domains) so that the viewing angle of the transflective LCD is increased.

As shown in Fig. 3, a liquid crystal top view of FIG. 1B, in a pixel 330 defined by a gate line 310 and a data line 320, the reflective area 340 corresponds to the opaque portion 132 in Fig. 2B and the transmissive area 350 corresponds to the transparent portion 134 in Fig. 2B, the liquid crystal molecules 152 added with chiral agent according to the invention has a twisting light property and a continuous domain having different molecular alignment, thereby increasing the viewing angle of the transflective LCD.

Thus, the present invention provides a method of forming a transflective liquid crystal display device with a wide-viewing angle. The present method utilizes an asymmetric electric field occurring at the fringe portion of the reflective electrode and the opening located at the transparent portion of the reflective electrode, causing the negative type liquid crystal molecules added with a chiral agent to tilt and have different molecular alignment. Moreover, the protrusion formed around the reflective electrode enhances molecule tilt. Thus, a continuous domain is formed in each pixel, thereby widening the viewing angle of a transflective LCD.

Finally, while the invention has been described by way of example and in terms of the above, it is to be understood that the invention is not limited to the disclosed embodiments. On

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the contrary, it is intended to cover various modifications and similar arrangements as would be apparent to those skilled in the art. Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such  
5 modifications and similar arrangements.

**What Is Claimed Is:**

1        1.    A method of forming a transflective liquid crystal  
2 display device with a wide-viewing angle, comprising the steps  
3 of:

4        providing a first substrate and a second substrate opposite  
5            the first substrate;

6        forming an insulating layer having an uneven surface on the  
7            first substrate;

8        forming at least one opening in the insulating layer;

9        forming a conformal reflective electrode on a sidewall and  
10           a bottom of the opening and part of the insulating  
11           layer, wherein the reflective electrode has at least  
12           one opaque portion and at least one transparent  
13           portion, and the transparent portion of the  
14           reflective electrode is located in the opening;

15       forming a conformal first alignment film on the reflective  
16           electrode;

17       forming a common electrode on an inner surface of the second  
18           substrate;

19       forming a second alignment film on the common electrode;  
20           and

21       forming a liquid crystal layer between the first substrate  
22           and the second substrate, wherein the liquid crystal  
23           layer comprises negative type liquid crystal  
24           molecules and a chiral agent.

1        2.    The method according to claim 1, further comprising  
2 the step of:

3       forming at least one symmetric protruding element on the  
4               insulating layer located around the reflective  
5               electrode.

1       3.    The method according to claim 2, wherein the symmetric  
2 protruding element has a triangular cross-section.

1       4.    The method according to claim 1, wherein, when a  
2 voltage is applied between the reflective electrode and the  
3 common electrode, an asymmetric electric field occurs at a  
4 fringe portion of the reflective electrode.

1       5.    The method according to claim 1, wherein the opaque  
2 portion of the reflective electrode is an aluminum layer.

1       6.    The method according to claim 1, wherein the  
2 transparent portion of the reflective electrode is an ITO  
3 (indium tin oxide) layer.

1       7.    The method according to claim 1, wherein a rubbing  
2 treatment is not performed on the first alignment film.

1       8.    The method according to claim 1, wherein a rubbing  
2 treatment is not performed on the second alignment film.

1       9.    A method of widening a viewing angle of a  
2 transflective liquid crystal display device, comprising the  
3 steps of:

4       providing a first substrate and a second substrate opposite  
5               the first substrate;

6       forming a transparent insulating layer having an uneven  
7               surface on the first substrate;

8       forming at least one opening in the insulating layer;

9           forming a conformal reflective electrode on a sidewall and  
10           a bottom of the opening and part of the insulating  
11           layer, wherein the reflective electrode has at least  
12           one opaque portion and at least one transparent  
13           portion, and the transparent portion of the  
14           reflective electrode is located in the opening;  
15           forming at least one symmetric protruding element on the  
16           insulating layer located around the reflective  
17           electrode;  
18           forming a conformal first alignment film on the reflective  
19           electrode and the symmetric protruding element;  
20           forming a common electrode on an inner surface of the second  
21           substrate;  
22           forming a second alignment film on the common electrode;  
23           and  
24           forming a liquid crystal layer between the first substrate  
25           and the second substrate, wherein the liquid crystal  
26           layer comprises negative type liquid crystal  
27           molecules and a chiral agent.

1           10. The method according to claim 9, wherein the symmetric  
2           protruding element has a triangular cross-section.

1           11. The method according to claim 9, wherein, when a  
2           voltage is applied between the reflective electrode and the  
3           common electrode, an asymmetric electric field occurs at a  
4           fringe portion of the reflective electrode.

1           12. The method according to claim 9, wherein the opaque  
2           portion of the reflective electrode is an aluminum layer.



1        13. The method according to claim 9, wherein the  
2 transparent portion of the reflective electrode is an ITO  
3 (indium tin oxide) layer.

1        14. The method according to claim 9, wherein a rubbing  
2 treatment is not performed on the first alignment film.

3        15. The method according to claim 9, wherein a rubbing  
4 treatment is not performed on the second alignment film.